Raman Scattering Characterization of annealed GaNAs layers

T.Furuhata, T.Kitano, H.Magara[*], A.Masuda[**], A.Yamaoto and A.Hashimoto
S.Tanaka[***], M.Takahashi[****], A.Moto[***], T.Tanabe[***] and S.Takagishi[***]

Department of Electrical and Electronics Engineering,
Fukui University, Bunkyo 3-9-1, Fukui 910, Japan
*Fukui Prefecture Industrial Technology Center
61-10 Kawaiwashizuka, Fukui, Fukui 910-0012, Japan
** School of Materials, Japan Advanced Institute of Science and Technology
1-1Asahidai, Tatsunokuchi, Ishikawa 923-1292, Japan
***Basic High-Technology Laboratories. ****Opto-Electronics Laboratories
Sumitomo Electric Industries, Ltd., 1-1-1, Koya-kita, Itami, Hyogo,
664-0016 Japan
hasimoto@kyomu1.fuee.fukui-u.ac.jp.

GaNAs alloys have been intensively investigated to fabricate the III-V light-emitting devices for optical communication. They have peculiar properties compared with the conventional III-V alloys, such as a large red shift of bandgap energies. However, the crystal quality of reported GaNAs layers grown by MOMBE or MOCVD techniques rapidly degrade as increase of the nitrogen (N) molar fractions. In the case of MOCVD growth, the photoluminescence (PL) intensity from the GaNAs layers become strongly by an annealing process after growth. Recently, Tanaka et al. have reported that the hydrogen (H) atoms of the N-H bonds existed in the as-grown GaNAs layers are the origin of the PL intensity suppressin[1)]. On the other hand, Mintairov et al, have reported that the formation of the partially natural superlattice would be expected in the GaNAs system from the results of Raman scattering observations[2)]. The Raman scattering spectroscopy is a sensitive technique to study the local structures of the impurity incorporations and the deviations from a long range order induced by the incorporation of the guest atoms. Therefore, the Raman scattering from the annealed GaNAs samples is very interesting. In the present paper, we have reported the Raman scattering characterization for the as-grown and the annealed GaNAs layers to investigate the local structures such as the partially ordered structures in an annealed GaNAs layer.

GaNAs samples were grown on GaAs(001) substrates with about 1 μm thickness by the MOCVD techniques. The N concentration was determined the present by X-ray diffraction (XRD) and secondary ion mass spectroscopy (SIMS). The molar fractions of N of two GaN_xAs_{1-x} samples were 0.79% and 1.2%. The annealing process was performed under flowing AsH_3 at 500℃ for 10min.The microscopic Raman scattering measurements were performed in the back scattering geometry at room temperature using a 632.8nm He-Ne laser.

Figure 1 shows the typical Raman spectra from a semi-insulator (S.I) GaAs substrate and the GaNAs grown layers. Longitudinal-optical (LO_1) and transverse-optical (TO_1) modes of the GaAs components were observed at 291cm^{-1} and 268cm^{-1} in both the GaAs and the GaNAs layers. Additionally, as shown in Fig.2, a weak shoulder near 257cm^{-1} on the low-wave-number side of TO_1 and the new mode appeared is the only GaNAs samples denoted by LO_2. The LO_2 were also observed near 470 cm^{-1}. Figure 3 shows the Raman spectra of the LO_2 mode for the $GaN_{0.012}As_{0.988}$ samples measured in the (xy) and (xx) configuration. The LO_2 mode clearly is observed in both configurations. According to Mintairov et al.[2)], the existence of the LO_c and the LO_2 modes indicate the strongly confined GaAs-like and GaN-like phonon modes, respectively. Therefore, it strongly indicates the presence of the partially natural superlattice in the GaNAs layers.

Figure 4 shows the Raman spectra from an as-grown and an annealed GaNAs layers measured in the (xy) scattering configuration. It is found that the FWHM of the LO_2 modes the annealed GaNAs layers became narrower than it from the as-grown GaNAs layers. FT-IR measurements show that the hydrogen (H) atoms in the as-grown GaNAs layers were desorbed from the layer by anneal[1)]. The results indicate that Ga-N bonds are recovered through breaking of the N-H bonds by the annealing process.

In conclusions, the Raman results show the formation of the partially natural supperlattice in the MOCVD GaNAs system as pictrically shown in Fig.5. The H atoms the forms N-H bonds in the as-grown sample as shown in Fig.6. The annealing process would be effective for breaking of the N-H bonds and recovering of the Ga-N bonds in the partially natural superlattice.

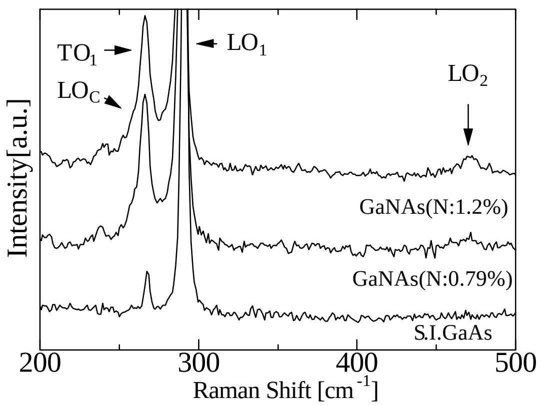

Fig.1. Typical Raman spectra for the S.I.GaAs and the GaN_xAs_{1-x} samples (x=0.0079,0.0012).

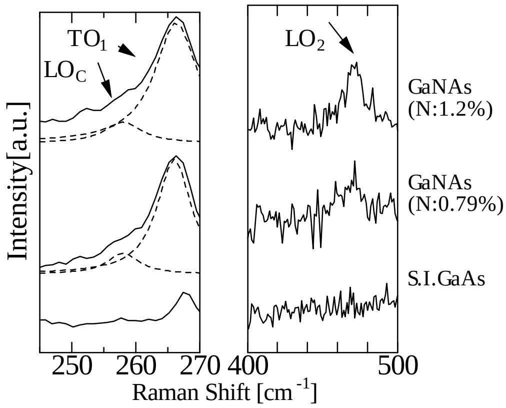

Fig.2. Typical LO_c,TO_c,and LO_2 Raman modes from the S.I.GaAs and GaN_xAs_{1-x} samples (x=0.0079,0.0012).

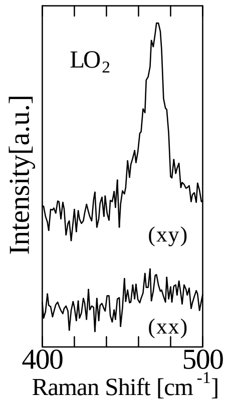

Fig.3. Typical polarized Raman modes from as-grown $GaN_{0.012}As_{0.988}$ samples.

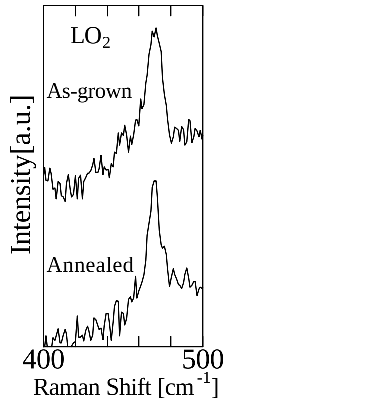

Fig.4. Typical LO_2 modes from the as-grown and the annealed $GaN_{0.0079}As_{0.9921}$ samples.

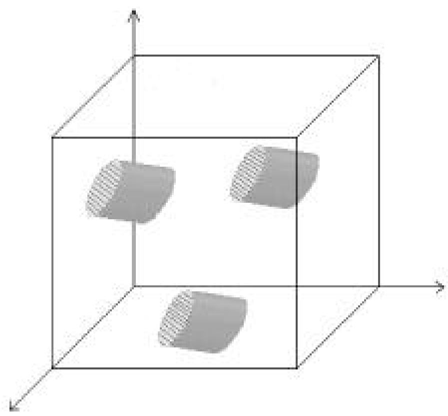

Fig.5. Schematic illustration of natural superlattice in a GaNAs layers.

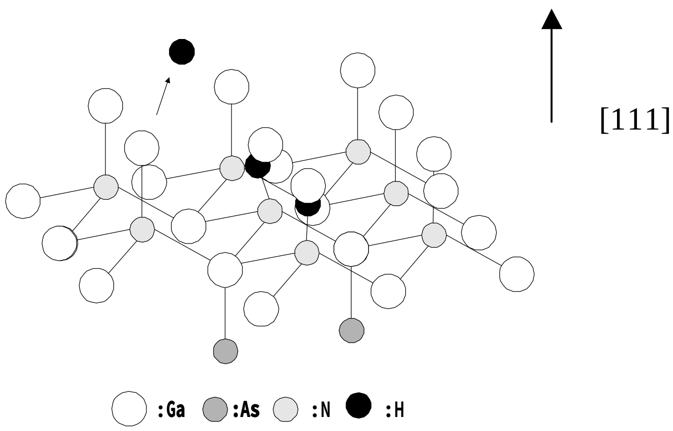

Fig.6. Proposed microscopic model of the H decomposition by the anneal

Reference

1) S.Tanaka, M.Takahashi, A.Moto, T.Tanabe and S.Takagishi, Extended Abstracts(The 46th Spring Meeting, 1999); The Japan Society of Applied Physics and Related Societies, **No1** p358

2) A.Mintairov, P. A. Blagnov, V. G. Melehin, and N. N. Faleev, J. L. Merz, Y. Qiu, S. A. Nikishin, and H. Temkin, Phys. Rev. **B 56**. 15836(1997)